REMARKS

This Amendment is being filed in response to the Office Action mailed on December 16, 2005. All objections and rejections are respectfully traversed.

Amendments to the Specification

The Specification has been amended to correct an obvious error in calculation. No new subject matter has been introduced.

Amendments to the Abstract

The Abstract has been amended to correct a typographical error. No new subject matter has been introduced.

Amendments to the Claims

Claims 1-22 are pending in the application. Applicant appreciates that the Examiner has found that Claims 8-11 and 14-17 contain allowable subject matter.

Claims 1, 6, 7, 12-14, 16, 18 and 19 have been amended to clarify the claims, and are not intended to narrow the scope of the claimed invention. No additional matter has been added.

Claims 1-7, 12, 13 and 18-22 have been rejected under 35 U.S.C. 102(b) as being anticipated by Eaves, U.S. Patent No. 5,656,915, issued on August 12, 1997 ("Eaves").

Claims 1, 18, 19 and 21 have been rejected under 35 U.S.C. 102(b) as being anticipated by Anzawa., US 2002/0109482 ("Anzawa").

Briefly, the present invention teaches a system for balancing state of charge among plural series connected electrical energy storage units that includes a power converter that selectively couples to an individual storage unit of a string of electrical energy storage units and transfers energy bidirectionally between the individual storage unit and the string of storage units.

One embodiment of the present invention as set forth in independent claim 1, as amended, comprises:

> A system for balancing state of charge among plural series connected electrical energy storage units, comprising:

a string of electrical energy storage units; and

a power converter selectively coupled to an individual storage unit of the string, the power converter configured to transfer energy bidirectionally between the individual storage unit and the string of storage units.

As described at Pages 12, 13, and 15 through 17 of the Specification, the present invention provides a system for balancing state of charge using a power converter selectively coupled to individual electrical energy storage units in a string of storage units, and bidirectional transfer of energy between individual storage units and the string of storage units. As illustrated in Fig. 5, the present invention uses a switch matrix to selectively couple individual storage units to a shared cell monitor and converter. As a result, the full string of storage units can be balanced with a substantial reduction in overall circuitry. Bidirectional switches may enable both the transfer of energy from an individual storage unit to a string of storage units, or from the string of storage units to an individual storage unit.

As described at Pages 8 and 9 of the Specification, the term "state of charge" refers to a measure that characterizes electrochemical state of a cell after a charging or discharging process. State of charge refers to the quantity of charge present in a cell at a given moment as a fraction of the total charge the cell is able to store.

Equalization of cell *terminal* voltage as practiced in the prior art differs significantly from equalization of "state of charge." In prior art techniques, the readily accessible cell terminal voltage is measured and used as an indicator of cell equalization. However, simply measuring cell terminal voltage in order to equalize cells has drawbacks, because cells having the same terminal voltage may not have the same state of charge.

Cell terminal voltage provides an unreliable measure of state of charge when the string of cells is either providing current to an external load (e.g., hybrid electric vehicle motor) or receiving current from a charging source (e.g., vehicle motor acting as a generator to provide braking action). If the cell string is at rest and neither supplying load current or receiving charging current then cell terminal voltage is equal to cell *internal* voltage which can be used to assess state of charge. However, when cell string load or charging current is flowing, the terminal voltage is lower or higher than the cell internal voltage respectively because of voltage developed across the cell impedance due to the load or charging current flow through it. If two cells have identical state of charge but different impedances, the cells will manifest different

terminal voltages when load or charging current is present. If a cell balancing system then equalizes those terminal voltages, it will create an imbalance in the state of charge where one did not previously exist. Because quite small voltage differences correspond to very significant state of charge differences, failure to correct for impedance effects can produce large cell balancing errors. Therefore, the use of "state of charge" accounts for the internal impedance of cell, allowing for cell balancing during charging and discharging conditions which prevail in practical applications, e.g., equalization of cells in a hybrid electric vehicle or laptop computer battery pack.

According to particular embodiments of the invention, both cell terminal voltage and cell current, are measured under load to enable computation of compensation for the current induced voltage drop or rise across the cell impedance. The state of charge may then be equalized by correcting for the voltage difference that is due to the load and impedance differences and then comparing voltages of individual cells.

Independent claim 1 recites the limitation of a power converter configured "to transfer energy bidirectionally between [an] individual storage unit and [a] string of storage unit" in a system for balancing state of charge.

I. The Rejections Under 35 U.S.C. 102(b)

Claims 1-7, 12, 13 and 18-22 were rejected under 35 U.S.C. 102(b) as anticipated by Eaves. Claims 1, 18, 19 and 21 were rejected under 35 U.S.C. 102(b) as anticipated by Anzawa.

A. Eaves and the Present Invention

Eaves teaches a power distribution unit for series connected multi-cell battery packs allowing individual control of cells that allows for regulating output voltage during discharge to an external load. In Eaves, for voltage equalization among storage units, charge transfer occurs through the use of a flying capacitor. *See* Col. 13, lines 10 – 28. Generally, the use of flying capacitors provides a slow method of cell balancing. Eaves has further slowed the process by placing a resistor in series with the capacitor, thus lengthening both charge and discharge times for the capacitor.

As discussed above, the present invention relates to the equalization of state of charge among plural series connected electrical energy storage units. Rather than dealing with equalization of state of charge, the system disclosed in Eaves teaches the equalization of cell voltage. Col. 7, lines 29 – 38. As stated above, "state of charge" balancing accounts for the internal impedance of cell, allowing for cell balancing during charging and discharging conditions. Eaves specifically states that its system has the ability to pass cell energy from cells with higher charge to cells of lower charge "during idle periods." *See* Col. 3, lines 30-33.

Furthermore, the present invention, as exemplified by independent Claim 1, includes a power converter that selectively couples to an individual storage unit of the string of electrical energy storage units and transfers energy bidirectionally between the individual storage unit and the string of storage units. The use of a flying capacitor in Eaves, however, does not provide the bidirectional transfer of energy between an individual storage unit and a string of storage units as claimed in the present invention. Eaves switches a group of cells to a resistor-capacitor (RC) circuit, then to another cell. *See* Col. 13 lines 20-26. In the cell equalization mode, Eaves does not store energy in the depicted transformer. Because the RC circuit has no gain, it can only transfer energy to a cell (or group of cells) with a lower voltage. In this manner, the transfer of energy in Eaves can only occur between a string of cells to a single cell, or from a string of cells at higher voltage to another string (group) of cells at lower voltage.

Eaves would be unable to transfer energy using a flying capacitor from a single cell to the entire group as contemplated by the present invention. This is because the entire string of storage units includes the individual storage unit (and would thus have a voltage at least equal to the individual storage unit), In other words, Eaves does not disclose the bidirectional transfer between an individual storage unit and a string of storage units because the system disclosed in Eaves can only transfer energy from a group of cells at a higher voltage to a group of cells at a lower voltage (the capacitor must be charged from one and then discharged to the other, respectively).

Applicants respectfully submit that Claims 1-22 are not anticipated by Eaves and thus are in condition for allowance.

B. <u>Anzawa and the Present Invention</u>

Anzawa teaches a voltage equalizing apparatus using a multi-secondary transformer and a flyback converter with a plurality of secondary windings for each battery in a series of connected battery strings.

The present invention differs from the teachings of Anzawa in several respects. First, the present invention relates to the equalization of state of charge among plural series connected electrical energy storage units. Second, as illustrated in Fig. 5, the present invention uses a switch matrix to selectively couple individual storage units to a cell monitor and converter. The cell monitor and converter circuit is shared by multiple storage units by selectively coupling the circuit to individual storage units. As a result, the full string of storage units can be balanced with a substantial reduction in overall circuitry. Third, the present invention teaches bidirectional switching. Switches may be enabled to both charge an individual cell from a string of cells, or discharge an individual cell to the string of cells.

Applicants respectfully submit that Anzawa practices voltage equalization, not ***state of charge*** equalization, and would not provide the balancing of state of charge as intended by the present invention. As mentioned above, the equalization of voltage, as performed by Anzawa, is not the same as an equalization of state of charge. Under a charging or discharging condition, voltage measurements may be affected. Notably, Anzawa states that equalization is preferably not performed during bulk charge or discharge. Col. 10, lines 41-49. However, as discussed above, the use of a state of charge measurement in the present invention allows for equalization under a charging or discharging condition.

Further, Anzawa uses a multi-secondary transformer and flyback converter with one secondary winding for each cell. This configuration of Anzawa does not allow for the system to target specific cells. Therefore, Anzawa does not provide the system for balancing state of charge that includes a power converter selectively coupled to an individual storage unit of the string or the transfer of energy bidirectionally, as claimed by independent Claim 1 of the present invention.

Applicants respectfully submit that Claims 1, 18, 19 and 21 are not anticipated by Anzawa and thus are in condition for allowance.

Information Disclosure Statement

An Information Disclosure Statement (IDS) was filed on July 1, 2004. A Supplemental IDS is being filed concurrently herewith. Entry of the IDS is respectfully requested.

CONCLUSION

In view of the above amendments and remarks, it is believed that all claims are in condition for allowance, and it is respectfully requested that the application be passed to issue. If the Examiner feels that a telephone conference would expedite prosecution of this case, the Examiner is invited to call the undersigned.

Respectfully submitted,

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Dated: 5/16/06